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Udo Broll
Soumyatanu Mukherjee
Rudra Sensarma

Editors: Faculty of Business and Economics, Technische Universität Dresden.

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Exchange Rate Volatility and Exports: Estimation of Firms Risk Preferences

Udo Broll[†]
Technische Universität Dresden

Soumyatanu Mukherjee[‡]
Indian Institute of Management (IIM), Kozhikode

Rudra Sensarma[§]
Indian Institute of Management (IIM), Kozhikode

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Abstract

In this companion paper to Broll and Mukherjee (2017), we empirically analyse how exchange rate volatilities affect firms optimal production and exporting decisions. The firms elasticity of risk aversion determines the direction of the impact of exchange rate risk on exports. Based on a flexible utility function that incorporates all possible risk preferences, a unique structurally estimable equation is used to estimate the risk aversion elasticities for a panel of Indian service sector (non-financial) firms over 2004-2015, using the quantile regression method.

JEL classification: D21; D81; F10; F31

Keywords: Exports; exchange rate volatility; risk aversion

[†]Faculty of Business and Economics, School of International Studies (ZIS), TU Dresden, 01062 Dresden, Germany.

[‡]Corresponding author. IIM Kozhikode, India; Faculty Block I, IIMK Campus, P.O. Kozhikode 673570, India. E-mail: smukherjee@iimk.ac.in (S. Mukherjee)

[§]IIM Kozhikode, India; Faculty Block I, IIMK Campus, P.O. Kozhikode 673570, India

Exchange rate volatility and exports: estimation of firms risk preference

1 Introduction

Broll and Mukherjee (2017) examines the optimal production and export decisions of a riskaverse domestic firm facing exchange rate uncertainty under meanvariance preferences, where the revenue risk stems from the uncertain movements in foreign (spot) exchange rate (see Broll and Mukherjee 2017; and the references therein). Putting the theoretical modelling framework of Broll and Mukherjee (2017) to work, this note quantitatively demonstrates how far are the risk preferences of the individual firms (producers) towards external market shocks responsible for the asymmetric export performances of the firms. Section 2 briefly recaps the theoretical framework of Broll and Mukherjee (2017) to arrive at the estimable equation. Section 3 describes the data and variables while Section 4 is devoted to the quantitative analysis based on Indian service sector (non-financial) firms over 2004-2015. The main novelty of this paper is to structurally estimate risk aversion elasticities of firms in the context of international trade. We propose a flexible utility function in a nonlinear mean standard deviation framework that nests all possible risk preference structures; based on which we derive a unique structural estimable equation for the empirical analysis. We use the quantile regression method (Koenker 2005) as it allows us to estimate the risk aversion elasticities across different levels of risk attitude of firms.

2 Theoretical framework[1]

Following Broll and Mukherjee (2017), the firm being producer of a single homogenous good at home under increasing marginal costs, serves both the domestic market and a foreign country market under exchange rate uncertainty. The firm faces a downward sloping residual demand curve both at home and abroad. Denoting the random spot exchange rate (expressed in units of the home currency per unit of foreign currency) as $\tilde{e}$; $p(x)$ as the price schedule of the exportable x in units of foreign currency; $p(y)$ as the price schedule of the product y sold in domestic market, in units of domestic currency; concave revenue functions in both home and foreign markets (in units of their respective currencies) as $R(x)$ and $R(y)$; we can express the random operating profit of the firm as $\Pi = \tilde{e}R(x) + R(y) - C(x + y)$.

The domestic firms preferences are given by a two-parameter flexible utility function that nests all possible risk preference structures (as in Saha 1997)

$$V(\mu, \sigma) = \mu^a - \sigma^b, \tag{1}$$

Where $\mu = \mu_e R(x) + R(y) - C(x + y)$ and $\sigma = \sigma_e p(x)x$ denote, respectively, the expected value and the standard deviation of $\tilde{p}i$. a and b are parameters.

[1] For details on the theoretical modelling section, see Broll and Mukherjee (2017).

We consider: $V_\mu(\mu,\sigma) > 0$ and $V_\sigma(\mu,\sigma) < 0$. for all μ,σ. With the definition of the marginal rate of substitution (MRS) between risk and return as: $S = -\frac{V_\sigma(\mu,\sigma)}{V_\mu(\mu,\sigma)} > 0$, the firm solves the following decision problem

$$\max_{x\geq 0, y\geq 0} V(\mu(x,y),\sigma(x,y)). \tag{2}$$

Considering only interior solutions of this problem[2], the equilibrium is given by

$$C'(x^* + y^*) = R'(y^*) \tag{3}$$

And

$$-\frac{V_\sigma(\mu,\sigma)}{V_\mu(\mu,\sigma)} = \frac{\mu_e R'(x^*) - C'(x^*+y^*)}{\sigma_e R'(x^*)} = \frac{b}{a}\mu(x^*,y^*)^{1-a}\sigma(x^*,y^*)^{b-1}. \tag{4}$$

The second order condition is satisfied due to the quasi-concavity of $V(\mu,\sigma)$.

Equation (3) states that the total amount of production of the firm is independent of the firms attitude towards risk and of the probability distribution of the random marginal export revenue. However, the allocation of production between domestic supply and exports depends on the firms risk preferences.

The term $\mu_e R'(x^*) - C'(x^* + y^*)$ in Equation (4) is merely the expected change in the mark-up.[3]

Broll and Mukherjee (2017) defines $\varepsilon_\sigma(\mu,\sigma) = \frac{\partial S(\mu,\sigma)}{\partial \sigma}\frac{\sigma}{S(\mu,\sigma)}$ as the elasticity of the MRS between risk and return with respect to the standard deviation of the firms end of period profit, ceteris paribus; and $\varepsilon_\mu(\mu,\sigma) = \frac{\partial S(\mu,\sigma)}{\partial \mu}\frac{\mu}{S(\mu,\sigma)}$ as the elasticity of the MRS between risk and return with respect to the mean of the end of period profit, ceteris paribus.

From Equation (4), it is easy to obtain

$$(\frac{\partial x^*}{\partial \sigma_e}) < 0, \text{ if and only if } \quad \varepsilon_\sigma(\mu(x^*,y^*),\sigma(x^*,y^*)) > -1. \tag{5}$$

Therefore, a risk-averse exporting firm may reduce its optimal export x^* upon an increase in risk, σ_e, if and only if $\varepsilon_\sigma(\mu^*,\sigma^*) > -1$.

An increase in revenue risk (brought about by the uncertain exchange rate movements in the world market) leads to a substitution effect and an income effect (or wealth effect). The total effect on export supply depends on the relative magnitudes of the income and substitution effects. Moving on to the relationship between the firms exports and domestic sales with respect to a change in the expected foreign exchange rate, i.e., μ_e, it is straightforward to show from Equation (4) that

$$(\frac{\partial x^*}{\partial \mu_e}) > 0, \text{ if and only if } \quad \varepsilon_\mu(\mu(x^*,y^*),\sigma(x^*,y^*)) < 1. \tag{6}$$

[2]Corner solution would have been relevant only if we would allow for zero exports. This point is illustrated in Broll and Mukherjee (2017).

[3]It is easily verifiable that if this expected change in the mark-up is non-positive, the optimum export is zero.

Owing to an increase in the expected foreign exchange rate at a given risk, a risk-averse exporting firm may optimally increase exports at the intensive margin if and only if $\varepsilon_\mu < 1$.

Therefore, the comparative statics of parameter changes depend on how sensitively the firms risk aversion, i.e., its willingness to pay for additional risks, responds to changes in expected final random profit and profit risk. What we show in this note is that different exporting firms at the intensive margin have different willingness to pay for additional risks that can be guided by the extent of the 'financial constraints' faced by different firms in the face of external shocks.

From Equation (4) it is easy to infer

$$\ln S_{it} = \ln\frac{b}{a} + (1-a)\ln\mu_i + (b-1)\ln\sigma_i. \tag{7}$$

Hence we obtain $\varepsilon_\sigma = (b-1)$ and $\varepsilon_\mu = (1-a)$.

Equation (5) implies the firms optimum exports decreases when the revenue risk increases owing to greater volatility in the foreign exchange rate if and only if $(b-1) > -1$. Similarly Equation (6) implies the firm will optimally export more when expected revenue increases if and only if $(1-a) < 1$.

To quantitative validate the above propositions, we use Equation (7) for estimating the following unique structural equation:

$$\ln S_{it} = \beta_1 + \beta_2\ln\mu_i + \beta_3\ln\sigma_i + \phi\gamma_t + u_i t. \tag{8}$$

$\phi\gamma_t$ represents time effects. We are going to estimate $\beta_2(= (1-a))$ and $\beta_3(= (b-1))$ across the entire risk distribution (i.e. of S). Hence we employ the quantile regression method (Koenker 2005). This is a widely used estimation technique when it comes to examining the impact of explanatory variables at different points of the distribution of the dependent variable. Standard OLS techniques concentrate on estimating the average response to changes in values of the explanatory variables. Quantile regression allows us to estimate the impact of a set of explanatory variables conditional on the selected quantile of the dependent variable. Once the coefficients are estimated, standard errors are generated by bootstrap replications to avoid imposing distributional assumptions which is also one of the advantages of this method.

3 Data and variables

Our data-set consists of 85 exporting non-financial service sector firms[4] operating from India during 2004-2015. The firm-level data are obtained from *Prowess IQ Database* of the Centre for Monitoring the Indian Economy (CMIE) while macroeconomic data are collected from the website of the Reserve Bank of India.

[4]We exclude financial sector firms as they are not engaged in exports. We consider services sector firms as they have been seen to be the most responsive to exchange rate volatility (Cheung and Sengupta 2013). We include only those firms that have positive exports during the entire time period.

We now define the main variables of our interest. We begin with a measure for the dependent variable.

S_{it}: Firm's attitude towards risks arising from exchange rate volatilities at the firm level; measured as Financial Vulnerability$_{it}$ $\times$ REER Volatility$_t$.

"Financial Vulnerability" is measured as ratios of firms net fixed assets to total assets, captures a firms reliance on the external sources of financing (Cheung and Sengupta 2013) and thereby vulnerability of a firm to external shocks.

REER Volatility (σ_e) is computed as the yearly standard deviation of monthly log differences in the real exchange rate (Hericourt and Poncet 2014).

Moving on to the independent variables, μ_i, (expected relative net profit) is measured as the ratio of the 'predicted' profit to the mean profit at the firm level = $(\hat{M}_t/M_t)_i$ (Schmidt and Broll 2009). σ_i measures the standard deviation of the (log of) net profit.

4 Empirical results

The results from estimating equation (8) are reported in Table 1. The F-tests reported at the bottom of the table shows that the coefficients significantly differ across the quantiles which supports the use of quantile regression for the estimation. The risk attitude (S) of the firms towards foreign exchange rate fluctuations exhibits the following patterns.

Beginning with the intercept we note that β_1 (i.e.ln$\frac{b}{a}$) is statistically significant for all quantiles. Therefore the antilog of this term is also different from 0 for all quantiles. Hence we can safely infer that no firm in our sample is risk neutral (since $b \neq 0$). Next we find β_3, the coefficient of lnσ (which corresponds to ε_σ, in Equation (5)) is statistically significant with negative sign at the 10th, 40th, 50th, 60th, 70th, 80th and 90th quantiles. Since this term relates to $b-1$ in Equation (7), we can conclude that b is significantly less than unity in these quantiles of the risk distribution. Also, since $b-1$ is greater than -1 in these quantiles, we can deduce (i) $b > 0$, implying risk aversion, at least for the firms in the above mentioned quantiles of the risk distribution, and (ii) ($\frac{\partial x_{it}}{\partial \sigma_e} < 0$, for these firms. Furthermore, due to the fact that ($\frac{b}{a}$) is less than 1 (since its logarithm is found to be less than 0), the preference structure for the firms belonging to these quantiles is characterised by decreasing relative risk aversion (DRRA).

β_2 (which corresponds to ε_μ, in Equation (6)) is statistically significant from the 20th up to the 90th quantile of the risk distribution. This term relates to $1-a$ in Equation (7) and is seen here to be significantly positive for these quantiles of risk distribution. We can therefore conclude, at least for the firms in the 40th, 50th, 60th, 70th, 80th and 90th quantiles of the risk distribution, (i) non-existence of constant absolute risk aversion (CARA) (since $a \neq 1$) and the existence of increasing absolute risk aversion (IARA) (since $a < 1$) with DRRA; and (ii) $\frac{\partial x_{it}}{\partial \mu_e} > 0$.

Finally figure 1 plots the estimated values of $\varepsilon_\sigma(= b-1)$ and $\varepsilon_\mu(= 1-a)$ at different points of the distribution of the firms risk attitude. Noticeably, ε_σ is the lowest at the 10th quantile of the risk-distribution and rises until the 30th quantile. Thereafter, it follows an inverted-U-shaped path. As for ε_μ, we observe two humps in the range of values: the first is at the 20th quantile and the next is at the 60th quantile of the risk distribution.

Since we found β_2 is positive, an increase in expected foreign exchange rate (INR/US Dollar) appears to have encouraged all the firms in our sample to increase their exports over 2004-2015. But the responsiveness still varies across the firms as ε_μ is different for different firms (with two humps in the distribution for $(1-a)$). One plausible reason is the interplay between firm-specific substitution and income effects of the risk-taking capacity, which in turn, is guided by the extent of the financial constraints faced by different firms in our sample (i.e. whether the firm uses its own assets as collateral or borrows from external sources when exchange rate fluctuates).

4 Summary

This note, as a companion paper of Broll and Mukherjee (2017), serves as the first attempt to quantitatively link the asymmetries in firms differential export behaviour, owing to unexpected exchange rate movements, to the risk attitude of the firms, by explicitly estimating risk-aversion elasticities. All the Indian (non-financial) service sector firms in our sample seem to exhibit positive association of their export performance with the changes in the expected REER change, but negative association with the changes in the REER volatility during 2004-2015. As for their risk preference structure we find that they exhibit IARA and DRRA consistently at the 40th and above quantiles of the risk distribution.

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Table 1: Quantile Regression Results

Panel A: Results from regression firms' risk attitude on expected relative net profit and REER volatility

Dependent Variable: S	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**
$\ln \mu$	-0.121	0.232**	0.141*	0.165**	0.250**	0.478**	0.408**	0.278**	0.263**
	(0.160)	(0.085)	(0.068)	(0.062)	(0.076)	(0.100)	(0.067)	(0.068)	(0.051)
$\ln \sigma$	-0.451**	-0.210	-0.186	-0.363*	-0.386**	-0.398**	-0.341**	-0.270**	-0.128*
	(0.132)	(0.149)	(0.127)	(0.086)	(0.099)	(0.097)	(0.098)	(0.077)	(0.051)
Year Dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
$\ln(b/a)$	-3.016**	-2.527**	-2.118**	-2.009**	-1.713**	-1.506**	-1.135**	-0.784**	-0.680**
	(0.176)	(0.123)	(0.121)	(0.126)	(0.164)	(0.202)	(0.214)	(0.054)	(0.083)
Observations	1008	1008	1008	1008	1008	1008	1008	1008	1008
Psuedo R^2	0.081	0.075	0.088	0.098	0.107	0.116	0.132	0.159	0.212

Note: **, *, + are respectively denoting levels of statistical significance at 1%, 5% and 10% levels; standard errors are in parentheses.

Panel B: Testing equality of coefficients between consecutive quantiles: F-Stat ($Prob > F$)

Dependent Variable S	20%		30%		40%		50%		60%		70%		80%		90%	
	$\ln \mu$	$\ln \sigma$	$\ln \mu$	$\ln \sigma$	$\ln \mu$	$\ln \sigma$	$\ln \mu$	$\ln \sigma$	$\ln \mu$	$\ln \sigma$	$\ln \mu$	$\ln \sigma$	$\ln \mu$	$\ln \sigma$	$\ln \mu$	$\ln \sigma$
10% (13, 994)	6.68**	5.05*														
20% (13, 994)			1.70^{+}	0.08												
30% (13, 994)					0.13	8.18**										
40% (13, 994)							2.04^{+}	0.21								
50% (13, 994)									8.23**	0.05						
60% (13, 994)											0.79	0.87				
70% (13, 994)													4.55*	0.79		
80% (13, 994)															0.06	5.01*

Note: **, *, + are respectively denoting levels of statistical significance at 1%, 5% and 10% levels.

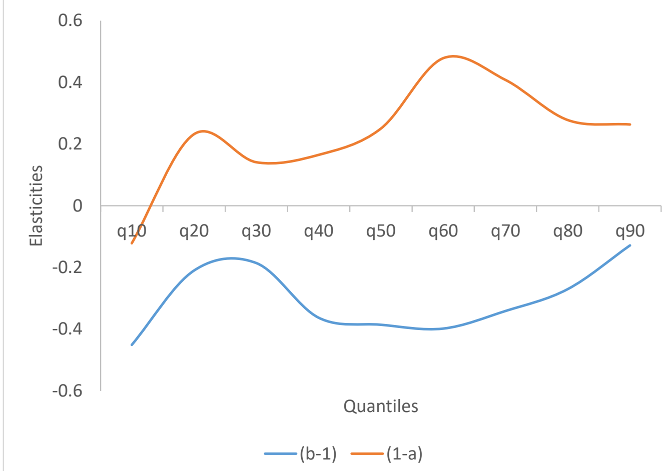

Figure 1: Risk Aversion Elasticities at Different Quantiles of the Distribution of *S*